MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 3, 2022/2023

EME4096 – INTERNAL COMBUSTION ENGINE

(ME)

5 OCTOBER 2023
09:00 a.m. – 11:00 a.m.
(2 Hours)

INSTRUCTIONS TO STUDENT

1. This Question paper consists of 7 pages including cover page with 4 Questions only.

2. Answer **ALL FOUR** questions. All questions carry equal marks and the distribution of the marks for each question is given.

3. Please write all your answers in the Answer Booklet provided.

Question 1

a) A two-stroke, four-cylinder diesel engine running at 2000 RPM develops 60 kW of brake power. Brake thermal efficiency is 30% and heating value of fuel (*QHV*) is 42 MJ/kg. Engine has a bore of 120 mm and stroke of 100 mm. Take $\rho_a = 1.15$ kg/m^3, air-fuel ratio = 15:1, $\eta_m = 80\%$, and $\eta_c = 95\%$. Calculate:

i) Total volume displacement of the engine in unit of m^3 **[2 marks]**

ii) Average piston speed in unit of m/s **[2 marks]**

iii) Torque engine in unit of Nm **[2 marks]**

iv) Fuel consumption in unit of kg/s **[3 marks]**

v) Air flow rate in unit of m^3/s **[2 marks]**

vi) Indicated thermal efficiency **[3 marks]**

vii) Volumetric efficiency **[3 marks]**

viii) Brake mean effective pressure in unit of kPa **[3 marks]**

ix) Specific emissions of hydrocarbon due to unburned fuel in unit of gm/kW-hr **[5 marks]**

Continued..

Question 2

An SI engine operates on an air-standard four-stroke Otto cycle as shown in **Figure 1**. Air- fuel enters the cylinders at 75°C and 130 kPa, and heat in by combustion equals q_{in} = 2000 kJ/kg. Compression ratio r_c = 9 and exhaust pressure P_{ex} = 100 kPa. Calculate:

i) pressure and temperature in intake stroke, point 1 based on **Figure 1**, [kPa, °C]

[2 marks]

ii) pressure and temperature in the end of compression stroke, point 2 based on **Figure 1**, [kPa, °C]

[4 marks]

iii) pressure and temperature in the end of combustion process, point 3 based on **Figure 1**, [kPa, °C]

[5 marks]

iv) pressure and temperature in the end of expansion stroke, point 4 based on **Figure 1**, [kPa, °C]

[4 marks]

v) Specific work produced during expansion stroke. [kJ/kg]

[3 marks]

vi) Specific work during compression stroke. [kJ/kg]

[3 marks]

vii) Specific pumping work. [kJ/kg]

[4 marks]

(Assume the C_p and C_v of air to be 1.004 kJ/kg.K and 0.717 kJ/kg.K respectively.

R is 0.287 kPa m^3 kg^{-1} K^{-1})

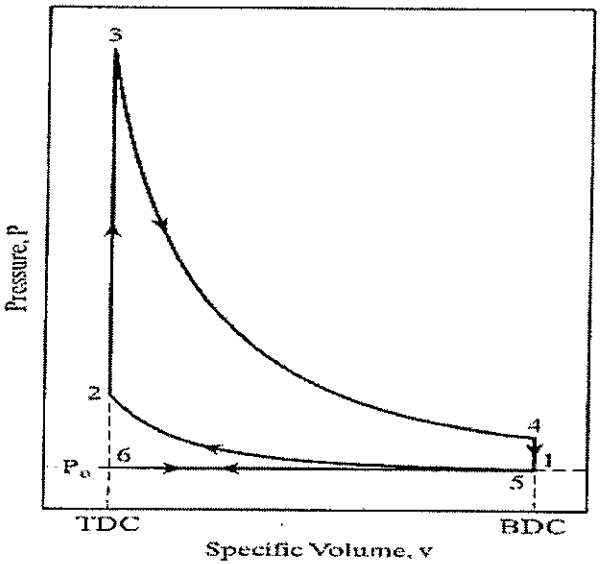

Figure 1: Air standard Otto cycle

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Question 3

a) A race car burns nitromethane with air at an equivalence ratio of 1.25. Except for unburned fuel, all nitrogen ends up as N_2 and all carbon ends up CO_2 (no CO).

i. Write the balanced chemical reaction equation,

[9 marks]

ii. Calculate the percent stoichiometric air [%], and

[3 marks]

iii. Calculate the air-fuel ratio.

[3 marks]

b) The spark plug in the cylinder of an SI engine is fired at 20° bTDC when the engine is running at 2400 RPM. Flame propagation mode starts at 10° bTDC and last for 0.001667 seconds. Calculate:

i) time of ignition and flame development in degrees of engine rotation, [degree],

[2 marks]

ii) time of ignition and flame development in real time, [sec],

[3 marks]

iii) crank angle when flame propagation mode ends, [degree after top dead center].

[5 marks]

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Question 4

a) In compression injection combustion, there are a series of events that occur after injection of fuel. List these events and explain them briefly.

[10 marks]

b) A 3 liter, V6, four stroke cycle SI engine is designed to have a maximum speed of 6800 rpm. At this speed, volumetric efficiency is 85%. The engine is equipped with a six barrel carburaters, each barrel having a discharge coefficient of $C_{Dt} = 0.95$. The fuel used is gasoline at AF 15 : 1. (Density of gasoline $\rho = 750$ kg/m^3 and density of air $\rho_{air} = 1.181$ kg/m^3). Calculate the:

i) Minimum throat diameter needed in each carburetor venture.

[7 marks]

ii) Fuel capillary tube diameter needed for each venture throat if tube discharge. (discharge coefficient, $C_{Dc} = 0.86$ and the capillary tube height differential is small).

[8 marks]

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Appendices

Table 1: Molecular weights

Substance		Molecular weight (kg/kgmole) or (lbm/lbmmole)
Air		28.97
Argon	Ar	39.95
Carbon	C	12.01
Carbon monoxide	CO	28.01
Carbon dioxide	CO_2	44.01
Hydrogen	H_2	2.02
Water vapor	H_2O	18.02
Helium	He	4.00
Nitrogen	N_2	28.01

Table 2: Thermodynamic Properties of Air

Temperature		c_p	c_v	$k = c_p/c_v$	Gas Constant $R = c_p - c_v$
K	°C	(kJ/kg-K)	(kJ/kg-K)		(kJ/kg-K)
273	0	1.004	0.717	1.40	0.287
298	25	1.005	0.718	1.40	0.287
300	27	1.005	0.718	1.40	0.287
500	227	1.029	0.742	1.39	0.287
850	577	1.108	0.821	1.35	0.287
1000	727	1.140	0.853	1.34	0.287
1500	1227	1.210	0.923	1.31	0.287
2000	1727	1.249	0.962	1.30	0.287
2500	2227	1.274	0.987	1.29	0.287
3000	2727	1.291	1.004	1.29	0.287

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Table 3: Properties of fuels

Fuel		Molecular weight	Heating Value		Stoichiometric		Octane Number		Heat of Vaporization (kJ/kg)	Cetane Number
			HHV (kJ/kg)	LHV (kJ/kg)	(AF)s	(FA)s	MON	RON		
Gasoline	C_8H_{15}	111	47300	43000	14.6	0.068	80-91	92-99	307	40-55
Light diesel	$C_{12.3}H_{22.2}$	170	44800	42500	14.5	0.069			270	35-50
Heavy diesel	$C_{14.6}H_{24.8}$	200	43800	41400	14.5	0.069			230	
Isooctane	C_8H_{18}	114	47810	44300	15.1	0.066	100	100	290	
Methanol	CH_3OH	32	22540	20050	6.5	0.155	92	106	1147	
Ethanol	C_2H_5OH	46	29710	26950	9.0	0.111	89	107	873	
Methane	CH_4	16	55260	49770	17.2	0.058	120	120	509	
Propane	C_3H_8	44	50180	46190	15.7	0.064	97	112	426	
Nitromethane	CH_3NO_2	61	12000	10920	1.7	0.588			623	
Heptane	C_7H_{16}	100	48070	44560	15.2	0.066	0	0	316	
Cetane	$C_{16}H_{34}$	226	47280	43980	15.0	0.066			292	100
Heptamethylnonane	$C_{12}H_{34}$	178			15.9	0.063				15
α-methylnaphthalene	$C_{11}H_{10}$	142			13.1	0.076				0
Carbon monoxide	CO	28	10100	10100	2.5	0.405				
Coal (carbon)	C	12	33800	33800	11.5	0.087				
Butene-1	C_4H_8	56	48210	45040	14.8	0.068	80	99	390	
Triptane	C_7H_{16}	100	47950	44440	15.2	0.066	101	112	288	
Isodecane	$C_{10}H_{22}$	142	47590	44200	15.1	0.066	92	113		
Toluene	C_7H_8	92	42500	40600	13.5	0.074	109	120	412	
Hydrogen	H_2	2	141800	120000	34.5	0.029		90		

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